Skeletal Adaptations to Different Levels of Eccentric Resistance Following Eight Weeks of Training

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ABSTRACT

INTRODUCTION: Coupled concentric-eccentric resistive exercise maintains bone mineral density (BMD) during bed rest and aging. **PURPOSE:** We hypothesized that 8 wks of lower body resistive exercise training with higher ratios of eccentric to concentric loading would enhance hip and lumbar BMD. **METHODS:** Forty untrained male volunteers (34.9±7.0 yrs, 80.9±9.8 kg, 178.2±7.1 cm; mean±SD) were matched for leg press (LP) 1-Repetition Maximum (1-RM) strength and randomly assigned to one of 5 training groups. Concentric load (% 1-RM) was constant across groups, but each group trained with different levels of eccentric load (0, 33, 66, 100, or 138% of concentric) for all training sessions. Subjects performed a periodized supine LP and heel raise (HR) training program 3 d·wk-1 for 8 wks using a modified Agaton Fitness System (Agaton Fitness AB, Boden, Sweden). Hip and lumbar BMD ($g \cdot cm^{-2}$) was measured in triplicate pre- and post-training using DXA (Hologic Discovery®). Pre- and post-training means were compared using the appropriate ANOVA and Tukey's post hoc tests. Within group pre- to post-training BMD was compared using paired t-tests with a Bonferroni adjustment. **RESULTS:** There was a main effect of training on L1, L2, L3, L4, total lumbar, and greater trochanter BMD, but there were no differences between groups. **CONCLUSION:** Eights wks of lower body resistive exercise increased greater trochanter and lumbar BMD. Inability to detect group differences may have been influenced by a potentially osteogenic vibration associated with device operation in the 0, 33, and 66% groups.

INTRODUCTION

- Prolonged exposure to microgravity leads to decreased bone mineral density (BMD), muscle mass, and strength (LeBlanc, 2000; Baldwin, 1996).
- Resistive exercise has been proposed (Baldwin, 1996) to prevent musculoskeletal deconditioning during space flight and has been shown to be protective during prolonged bed rest (Shackelford, 2004).
- The interim resistive exercise device (iRED) currently on the International Space Station (ISS) only provides a 60-70% eccentric:concentric loading ratio.
- The decreased eccentric loading capabilities of iRED may not provide adequate stimulation of bone (Schneider, 2003; Lee, 2004), resulting in the continued loss of BMD among astronauts on ISS (Lang, 2004).

PURPOSE

- The purpose of this study was to quantify the effects on BMD of eight weeks of resistive exercise training at five different percentages of eccentric to concentric loading: 0, 33, 66, 100, and 138%.
- We hypothesized that eight wks of resistive exercise training with eccentric overload would significantly increase hip and lumbar BMD more than when eccentric loads were less than or equal to the concentric load.

METHODS

- Forty males with no history of resistive exercise training in the previous six months participated in the study (Table 1).
- Subjects were screened using an Air Force Class III-equivalent physical examination and a dual-energy x-ray absorptiometry (DXA) lumbar spine scan to ensure general health and adequate BMD (> -2.0 SD of age-specific mean).
- Subjects completed whole body, lumbar, and hip DXA scans (Hologic Discovery®) in triplicate before and after 8 wks of lower body resistive exercise training. The mean of the three scans was used for statistical analysis.
- Concentric supine leg press (LP) and heel raise (HR) strength was measured as the maximum load a subject could lift one time (1-RM) using a modified Agaton Fitness System (Agaton Fitness AB, Boden, Sweden; Figure 1). Subjects completed three pre-training 1-RM tests and one post-training 1-RM. Tests were separated by at least five days.
- Subjects were matched for pre-training LP strength and randomly assigned to one of five training groups.
- Subjects performed a periodized strength training program ($3 d \cdot wk^{-1}$) in which the concentric loads were prescribed based upon the pre-training 1-RM. Eccentric loads were prescribed according to group assignment: 0, 33, 66, 100, or 138% (Figure 2).
- Pre- and post-training BMD was compared using a repeated measures ANOVA for between groups differences. Within-groups pre- to post-training BMD was compared using paired t-tests with a Bonferroni adjustment. Statistical significance was defined as $p < .05$.

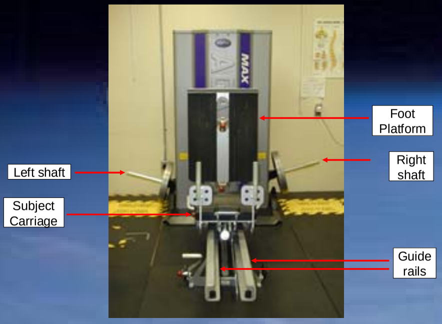

Figure 1: Leg press/heel raise exercise device

Table 1. Subject characteristics (mean±SE)

	0%	33%	66%	100%	138%
Age (yrs)	37 ± 3	36 ± 2	31 ± 2	37 ± 1	34 ± 3
Ht (cm)	179.2 ± 2.9	181.5 ± 2.1	177.3 ± 2.9	178.0 ± 2.3	175.3 ± 2.4
Pre-BW (kg)	79.4 ± 3.8	84.0 ± 2.7	81.4 ± 4.9	80.4 ± 3.5	79.2 ± 2.7
Post-BW (kg)	79.6 ± 4.0	84.9 ± 2.8	81.2 ± 4.8	80.4 ± 3.4	79.6 ± 2.4

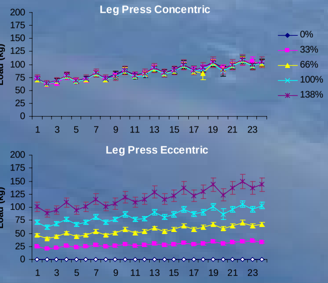

Figure 2. Mean (±SD) concentric and eccentric training loads across sessions

RESULTS

- Subjects completed 97% of training sessions.
- There was a main effect of training on greater trochanter, L1 through L4, and total lumbar BMD but there were no differences between groups (Figure 3).
- Greater trochanter BMD increased after training only in the 138% group.
- Total lumbar BMD increased in all groups except the 100% group.
- L1 and L2 BMD increased from pre to post-training in the 33 and 138% groups. L3 BMD increased in only the 33% group.
- L4 BMD increased from pre- to post-training in the 0, 33, and 66% groups. There was no change in the 100% and 138% groups.

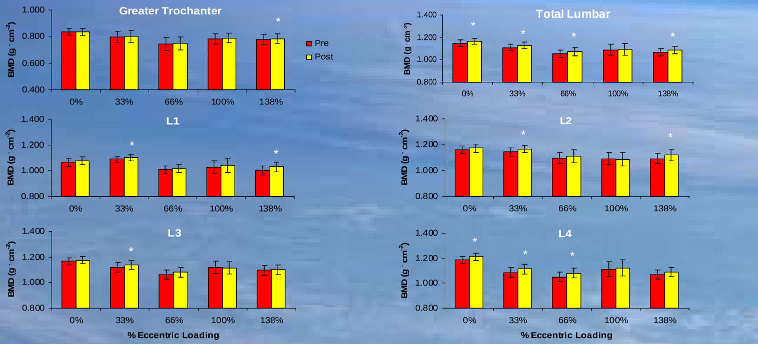

Figure 3: Pre- and post-training BMD in the hip and spine. *Significantly different from pre-training

DISCUSSION

- Supine lower body resistive exercise increased lumbar BMD after eight weeks of training but there was no effect of different levels of eccentric loading. Resistive exercise training also increased greater trochanter BMD, perhaps to a greater extent when overload training was performed.
- To our knowledge, this is the first study to show BMD increases measured by DXA after only eight weeks of resistive exercise.
- During underload operation, the exercise device produced a brief force impulse when transitioning from eccentric underload to the concentric load. This impulse, which was unique to the underload groups, may have influenced training-induced BMD changes and masked between group differences.
- Resistive exercise training may be an appropriate method to prepare crewmembers for long duration space flight and has been shown to protect bone during unloading (Shackelford, 2004). Coupled with a positive effect on muscle strength (Brandenburg, 2002), eccentric overload training may be a more efficient countermeasure to bone loss.

REFERENCES

Baldwin, KM, et. al. Musculoskeletal adaptations to weightlessness and development of effective countermeasures. *Med Sci Sports Exerc*, 28: 1247-53, 1996.
Brandenburg, JP and D Docherty. The effects of accentuated eccentric loading on strength, muscle hypertrophy, and neural adaptations in trained individuals. *J Strength Cond Res*, 16: 25-32, 2002.
Lang, T, et. al. Cortical and trabecular bone mineral loss from the spine and hip in long-duration spaceflight. *J Bone Miner Res*, 19: 1006-12, 2004.
LeBlanc, AD, et. al. Muscle volume, MRI relaxation times (T2), and body composition after spaceflight. *J Appl Physiol*, 89: 2158-64, 2000.
Lee, SM, et. al. Foot-ground reaction force during resistive exercise in parabolic flight. *Aviat Space Environ Med*, 75: 405-12, 2004.
Schneider, SM, et. al. Training with the International Space Station Interim Resistive Resistive Exercise Device. *Med Sci Sports Exerc*, 35: 1935-45, 2003.
Shackelford, LC, et. al. Resistance exercise as a countermeasure to disuse-induced bone loss. *J Appl Physiol*, 97: 119-29, 2004.